California Department of Transportation
Transportation System Information Program

Transportation System Performance Measures Pilot Projects

Technical Memorandum

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Booz·Allen & Hamilton Inc.
June 30, 2000

BOOZ·ALLEN & HAMILTON INC.

San Francisco
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To: Tremain Downey

From: Tarek Hatata

Subject: **Pilot Study Conclusions and Related Opportunities**

As you know, Booz, Allen has completed and submitted the pilot study results to the California Department of Transportation (Caltrans). This memorandum aims to summarize the conclusions of this effort and discuss opportunities to leverage the results of the performance measurement initiative into the planning and programming processes.

Conclusions

We conclude that using the three outcomes, namely mobility, reliability, and safety is (a): consistent with current processes, and (b): enhances some of the information provided to decision makers.

One of our pilot studies was conducted for the I-5 in San Diego. As we compared our results with the existing Project Study Report (PSR), we found that by and large the mobility and safety results were consistent.

However, the PSR did not address reliability or factors impacting reliability. These factors include queuing, flow rates, and possible operational impediments. Our analysis did identify reliability (or predictability) issues that may or may not be addressed through the proposed capacity expansion projects. Note that the PSR we reviewed is a typical Caltrans PSR and is in no way deficient. Our conclusion is that the PSR development could benefit from reliability analysis which could result in different project alternatives.

An additional finding is that performance measures can be aggregated at various levels. For instance, for the pilot study, mobility and reliability data was aggregated at the corridor level even though the underlying data is at much smaller segmentation level. The results can also be further aggregated, to the county or state level for a statewide analysis.

The pilot study conducted on a portion of State Route 99 from Elk Grove to Sacramento yields the following conclusions. The overall accident rate was about twice as high for the segment analyzed as it was for the I-5 corridor. Both AM and especially PM delay statistics were significantly less than in the San Diego case study even accounting for the fact that for SR 99 only Northbound data was available for analysis. From a reliability standpoint, several segments were identified with high travel time variability. This poor reliability tends to occur in the early morning (5-7 AM) and in the evening (6-8 PM), depending on the segment.

Opportunities

Completing these initial pilot studies identified conclusions that lead to opportunities for implementation of the performance measures initiative. These opportunities exist in the planning and programming processes as described below:

- Traffic Operations and Planning have the opportunity to work together to take advantage of the improved and new information developed via the performance measures initiative.

- As Caltrans moves to address congestion in the State, it is becoming increasingly clear that a total system management approach is needed. Such an approach would focus on operational as well as capacity related improvements. This approach is consistent with the Department's TOPS (Traffic Operations Strategy) initiative and with the entire direction of transportation planning and decision making.

- TCRs and PSRs can benefit from the combination of mobility and reliability analyses. Use of mobility and reliability can help to better balance short- and long-term benefits of operational strategies and capital expansion. In some cases, the operational strategies can yield higher benefits in a shorter time. Expansion projects are still critical but only after the system flow rates are optimized.

We also believe that a comparison among corridor reliability results could lead to identifying lessons learned from which the rest of the State can benefit. It is unclear to us why the two corridors show significant differences in reliability. Such differences should be analyzed and reviewed to start understanding the critical factors that affect reliability and how these factors can help to improve decision making.

In summary, the conclusions and opportunities stress the importance of incorporating reliability analyses into Caltrans'planning, programming, and operations processes. I hope we can continue to assist you and Caltrans in achieving that goal.

If you have any questions or comments, please do not hesitate to call me at 415-281-4914.

TAH

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LIST OF EXHIBITS

This document represents a summary of the regional level pilot projects conducted parallel to the development of the Performance Measures Status and Prototype Report for the California Department of Transportation (Caltrans), as part of the Performance Measures Initiative's third phase.

1. INTRODUCTION

The impetus to develop performance measure "pilot projects" was established in November of 1999. At that time Booz·Allen & Hamilton made a presentation to the Director of the California Department of Transportation (Caltrans) and a group that included Chief Deputy Directors, Deputy Directors, and District Directors.

The goal of the presentation was to help the highest levels of Caltrans understand performance measures and how these measures may be applied. Based on the presentation, Caltrans requested that Booz·Allen begin work on implementing system measures on one corridor as a case study.

District 11 (San Diego) initially was suggested as a potential partner for a case study. The Booz·Allen team worked with Caltrans to develop a set of criteria to select potential corridors for analysis. The Caltrans project management team also solicited input on candidate corridors from all twelve Caltrans Districts during the regular System Measure Work Group (SMWG) meetings.

Three candidate corridors evolved from this process: Two in District 3, and one in District 11. Exhibit 1-1 describes these corridors in more detail.

Exhibit 1-1
Three Candidate Pilot Projects

Pilot Study	**1**	**2**	**3**
District	**D-3**	**D-3**	**D-11**
Corridor Study	**SR 99 Sacramento to Elk Grove**	**I-80 Davis to Rocklin**	**I-5 Downtown San Diego to Oceanside**
Total Corridor Length	10 miles	26 miles	39 miles
Loop Data Available?	Yes, NB direction only	Yes, Partially: 2.7 miles EB	Yes: 32 miles NB, 37 miles SB
Principal Arterial	Yes	Yes	Yes
Inter-Regional Transit	No	No	Amtrak
Inter-Regional Route	Yes	Yes	Yes
HOV Lanes	Yes	No	No

At the time of the analysis, limitations existed on loop data availability for the corridors considered. For example, District 3 does not have complete loop detector coverage of its freeway system. The I-80 candidate corridor only covers a distance of about 2.7 miles between Truxel Road and Norwood Avenue and only in the eastbound direction. The SR-99 corridor has nearly 10 miles of data available, but only in the northbound direction. The I-5 corridor in San Diego County has nearly complete coverage between downtown San Diego and Oceanside. However, some sections of freeway along this corridor have long distances with no loops (with the longest being over four miles).

During the March 2000 SMWG meeting, the group decided to adopt the District 11 pilot on I-5 primarily because the corridor contained significant loop detector data. The fact that Amtrak provided a competing service to the automobile was also considered another important factor. Originally, only 13 miles in the southbound direction and five miles in the northbound direction would be considered. However, Booz·Allen recently received additional loop detector data from District 11 (i.e., 32 miles northbound and 37 miles southbound) and is able to perform the analysis between Oceanside and downtown San Diego as envisioned.

In the April 2000 policy meeting, a deputy director noted that the proposed District 11 corridor did not contain any High Occupancy Vehicle (HOV) lanes. He requested that a District 3 candidate for SR 99 (Sacramento to Lodi) be added to the study set. The policy committee decided to add the District 3 pilot study, defined as Sacramento to Elk Grove along SR 99.

This document represents the results of the Booz·Allen team analysis of these two corridors:

- District 3, 10 miles between Sacramento and Elk Grove on SR-99 northbound
- District 11, 37 miles between Downtown San Diego and Oceanside.

2. DISTRICT 3 ANALYSIS

The analysis of each pilot begins with a description of the corridor, then proceeds with performance results for safety, mobility and reliability.

2.1 Corridor Description

The District 3 corridor analyzed is SR 99 from Elk Grove to Sacramento.

The section analyzed runs from post mile 12.78 (Elk Grove Boulevard) to post mile 23.21 (12th Avenue). SR-99 along this segment is generally a two to three lane limited access freeway with one High Occupancy Vehicle (HOV) lane along the entire segment. Exits are generally spaced approximately every 1/2 to 1 mile. The segment passes through the communities of Elk Grove, Laguna Creek, Florin, and Fruitridge before ending in Sacramento at 12th Avenue. This area can be described as largely suburban residential.

Amtrak (San Joaquin corridor) runs along this corridor but does not compete for many passengers along the corridor since it is primarily an inter-city service.

The table listing each loop location by post mile for the highway is shown below in Exhibit 2-1.

Exhibit 2-1
District 3 SR 99 Northbound Loop Locations

Postmile	Location
12.8	Elk Grove Boulevard
13.8	EB Laguna Road
14.0	EB Laguna Road
15.8	EB Calvine Road
15.9	WB Calvine Road
17.7	WB Mack Road
19.5	EB Florin Road
19.7	WB Florin Road
20.8	EB 47th Avenue
21.0	WB 47th Avenue
21.9	EB Fruitridge Avenue
23.2	12th Avenue

Source: District 3 Traffic Operations

The results section is organized in three parts, mirroring performance measure results presented in the Performance Measures Status and Prototype Report:

- safety results
- mobility results
- reliability results.

Safety results are reported for the 10-mile segment covering both directions. The mobility and reliability results are reported for the northbound direction only. A brief summary of the approach used is presented before the actual performance results. The safety results are based on 7-day accident data, while mobility and reliability results are based on 5-day data (i.e., week-end data are not considered).

2.2 Safety Results

The source for the safety results is the 1999 Route Segment Report (RSR). This data source derives from the Traffic Accident and Surveillance Analysis System (TASAS), which is based on California Highway Patrol accident reports. The 1999 Route Segment Report safety statistics contain total accidents for 1996, 1997 and 1998. The statistics shown in this report therefore represent the average safety rates for the three-year period.

The segments from the RSR chosen as best corresponding to the corridor desired are shown below in Exhibit 2-2.

Exhibit 2-2
District 3 Pilot RSR Analysis Sample – Segment Descriptions

CO	RTE	SEG ID	PM	PM	FROM	TO	R/U	SEG LGTH	EXIST FAC
SAC	099	AM0638	013.78	014.86	ELK GROVE NORTH URBAN LIMITS	/SAC S URBAN LIMITS (SHEL	U	1.1	4F
SAC	099	AM0640	014.86	019.61	SAC SOUTH URBAN LIMITS (SHELDO	/FLORIN RD OC BR #24-150S	U	4.7	4F
SAC	099	AM0642	019.61	021.94	FLORIN ROAD OC BR #24-150S-167N	/FRUITRIDGE ROAD OC BR #	U	2.3	8F
SAC	099	AM0644	021.94	R024.35	FRUITRIDGE RD OC/RTE 50/51-RTE BRK		U	2.4	8F

Source: 1999 Route Segment Report

For each segment, the RSR lists the segment length, the Annual Average Daily Traffic (AADT), the Traffic - Daily Vehicle Miles (T-DVM) traveled on that segment (i.e., also know as vehicle miles traveled), as well as the accident totals and accident rates as calculated by Caltrans. The accident rate calculation uses as its primary (but not only) factor, T-DVM for the facility and that segment.

These are shown in Exhibit 2-3 below.

Exhibit 2-3
District 3 Pilot RSR Analysis Sample – Safety Data

CO	RTE	PM	PM	SEG LENGTH	AADT ('000s)	T-DVM ('000s)	ACCIDENT RATE
SAC	099	013.78	014.86	1.1	80.2	88	0.95
SAC	099	014.86	019.61	4.7	101.0	474	0.99
SAC	099	019.61	021.94	2.3	139.1	319	1.37
SAC	099	021.94	R024.35	2.4	172.6	414	1.24

Source: 1999 Route Segment Report

By calculating the weighted average accident rate over the length of the corridor (weighted by total T-DVM), one can calculate the overall accident rate for the entire corridor. The overall accident rate for the highway corridor for the D3 pilot is shown below in Exhibit 2-4.

Summary

The overall accident rate can be broken into auto and truck accident rates as shown below in Exhibit 2-4. In addition, fatality accident rates and injury accident rates can be computed. Note that two thirds of all accidents reported do not involve any fatalities or injuries. This is consistent with the District 11 pilot study findings.

Exhibit 2-4
District 3 SR 99 Pilot - Highway Safety Results

Overall accident rate:	1.161 accident per million VMT
- Auto accident rate:	1.132 accident per million VMT
- Truck accident rate:	0.029 accident per million VMT
Fatality accident rate:	0.004 accident per million VMT
Injury accident rate:	0.390 accident per million VMT

Source: 1999 Route Segment Report, Booz·Allen analysis

All accident rates are expressed in total million VMT, not auto VMT or truck VMT. The total includes both truck and auto types.

Trucks are defined as a combination of truck types corresponding to categories F through G6 in the Caltrans TSAR party type reference card. These include trucks with truck tractors, as well as truck/tractors with trailers, single unit tankers, and truck/tractors with tank trailers. Pick-up trucks are not included.

2.3 Mobility Results

Using loop detector data from District 3, the study team developed highway mobility results. Mobility is defined as the average point-to-point travel times resulting in travel delay. Delay is the additional travel time spent traveling due to less than optimal circumstances[1]. The highway mobility manual guidelines for this phase of the performance measures project were used to derive the mobility results for this pilot study.

In total, 102 weekdays (between August and December 1999) of data were collected from the loops on SR-99. This data was collected only for the northbound direction since southbound direction data were not available. The loop detector data provide the following information:

- loop location (e.g., ID number, route number, direction, postmile)
- date
- time
- speed
- traffic volume
- number of lanes at that location
- number of loops reporting data (note: not all lanes will have been equipped with working loop detectors).

Delay along a segment is calculated by subtracting free-flow travel time from the actual average travel time. The free-flow travel time is determined by the posted speed (i.e., Free-Flow Travel Time = Distance ÷ Posted Speed). Actual average travel time is determined by the actual speed of travel over the same distance.

To arrive at delay for any given time period (e.g., AM or hourly), the travel time for each segment of the highway is calculated for each day for that time period. The average travel time across the segment is the summation of all the travel times for all the days per time period divided by the total number of days for which there is data as illustrated in the following formula:

$$\text{Average Travel Time} = \left(\frac{\sum \text{Travel Times Across Segment}}{\text{Total Number of Days of Data}}\right)$$

1 *Note that the performance measure initiative definition of delay differs from the Caltrans Highway Congestion Monitoring (HICOMP) report methodology. The HICOMP report outlines all delay corresponding to speeds less than 35 miles per hour. The delay captured in this report is any delay due to less than posted speed travel. For more information on the mobility indicator, please consult the Transportation System Performance Measures, Compendium of Phase II Results, June 30, 1999.*

The loop detector data were tested for reasonableness. "Invalid" loop detector data were information representing:

- very little data reported (i.e., only one or two days of data)
- extremely high average speeds (i.e., in excess of 80 mph)
- extremely high average flow rates (i.e., more than 2,800 vehicles per hour per lane).

The AM period selected represents the time from 5:30 AM to 10:00 AM. The PM period represents the time from 1:30 PM to 8:00 PM.

Exhibit 2-5 shows the results of the delay analysis along the corridor for the AM and PM periods in tabular form. Exhibit 2-6 presents the same data graphically.

Exhibit 2-5
Segments Showing Highest Average Daily Vehicle Hours of Delay for the SR-99 Corridor

AM Commute Period

Location Description	Facility/ # Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total AM Delay (hours)	Hour of Maximum Delay
Laguna Rd to Mack Rd	3	1.9	40.3	4155	1.75	2.83	1.07	335	7:00 - 8:00
Mack Rd to Florin Rd	3	1.8	28.2	3616	1.66	3.83	2.17	588	7:00 - 8:00
47th Ave to Fruitridge Rd	3	1.1	30.5	1381	1.02	2.16	1.15	119	7:00 - 8:00

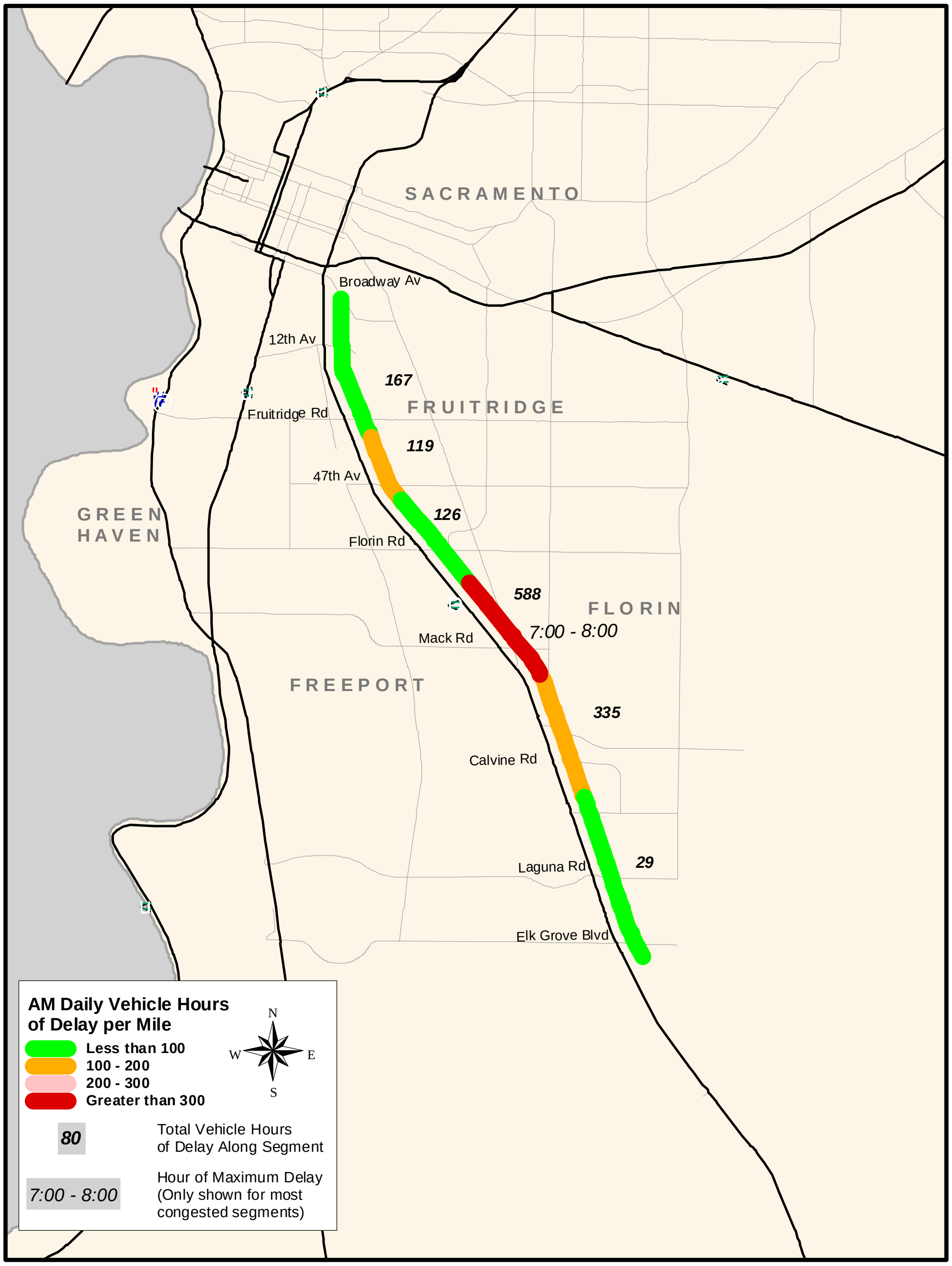
PM Commute Period

Location Description	Facility/ # Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total PM Delay (hours)	Hour of Maximum Delay
Laguna Rd to Mack Rd	3	1.9	40.3	3229	1.75	2.83	1.07	376	14:00 - 15:00
Mack Rd to Florin Rd	3	1.8	28.2	1954	1.66	3.83	2.17	459	14:00 - 15:00
47th Ave to Fruitridge Rd	3	1.1	30.5	2202	1.02	2.16	1.15	274	16:00 - 17:00

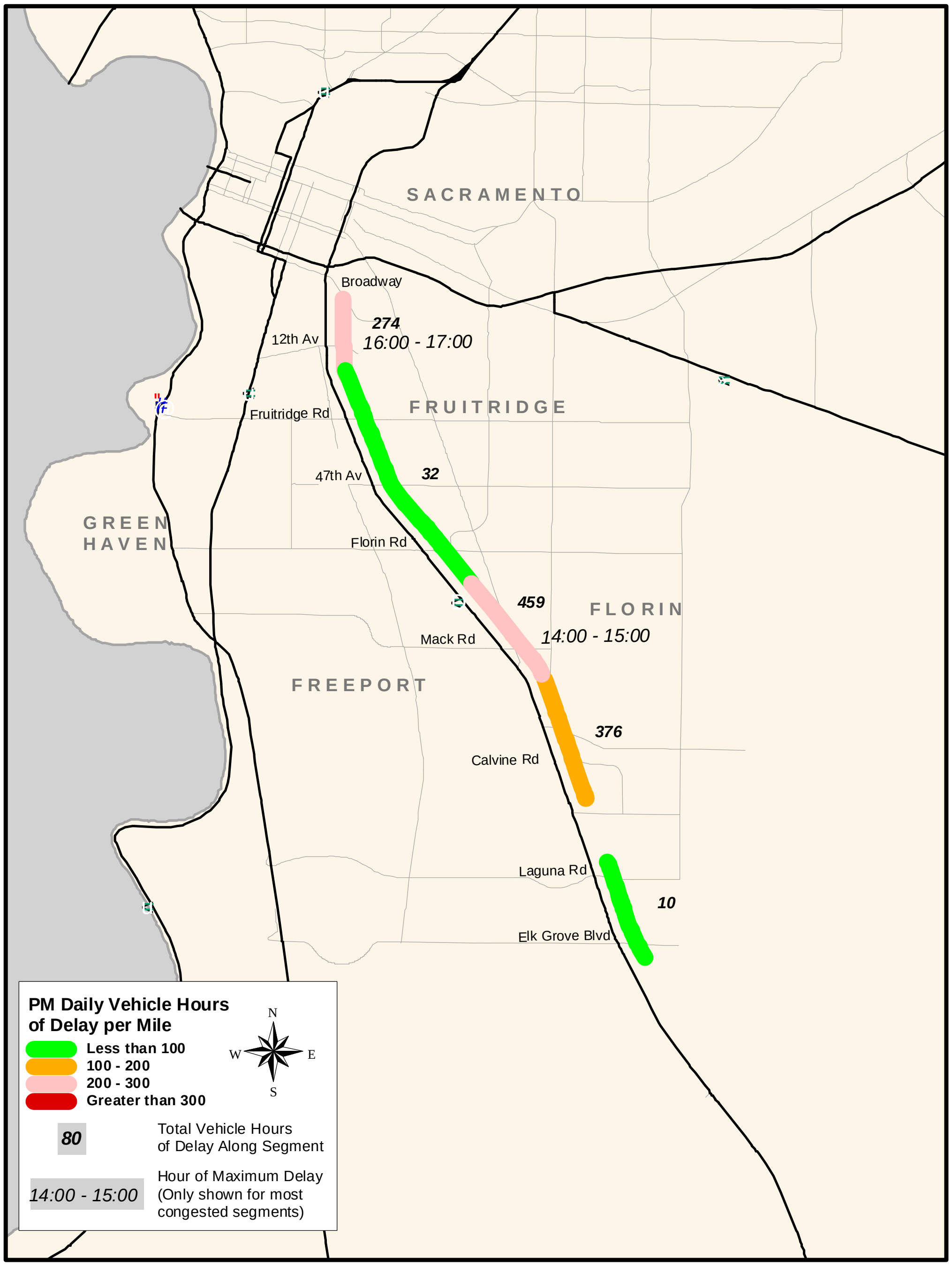
When comparing the table on this page to the exhibits, note that each total delay figure represents a *grouping* of segments experiencing similar levels of delay. The total delay shown represents the summation of the delay experienced on each individual segment. For example, the 335 total AM delay from Laguna Rd to Mack Rd represents the total for two smaller segments of delay data.

Exhibit 2-6
Average Daily Vehicle-Hours of Delay for the SR-99 Corridor by Time Period

Average AM Period Daily Delay



Average PM Period Daily Delay



Summary

In both time periods, congestion is consistently high between Calvine Road and Florin Road, with the majority of daily delay occurring before and after Mack Road. This section accounts for 68 percent of all AM period delay in the northbound direction (over 900 daily vehicle hours of delay). Congestion north of Mack Road accounted for the remaining congestion, particularly along the approaches to SR-50 and downtown Sacramento.

Comparison with PSR

A PSR was not available for comparison with this analysis.

2.4 Reliability Results

Reliability is measured as day-to-day variability in travel time between the expected travel time and the actual travel time. Reliability can be calculated by using statistical tools. The standard deviation is one tool to estimate how much the travel time on any given day will "deviate" from the average travel time. It provides the probable range of time that a motorist will arrive within his or her scheduled time.

$$\text{Standard Deviation of Travel Time} = \sqrt{\frac{\sum(\text{Travel Time on Day } n \text{ - Average Travel Time})^2}{\text{Number of Days - 1}}}$$

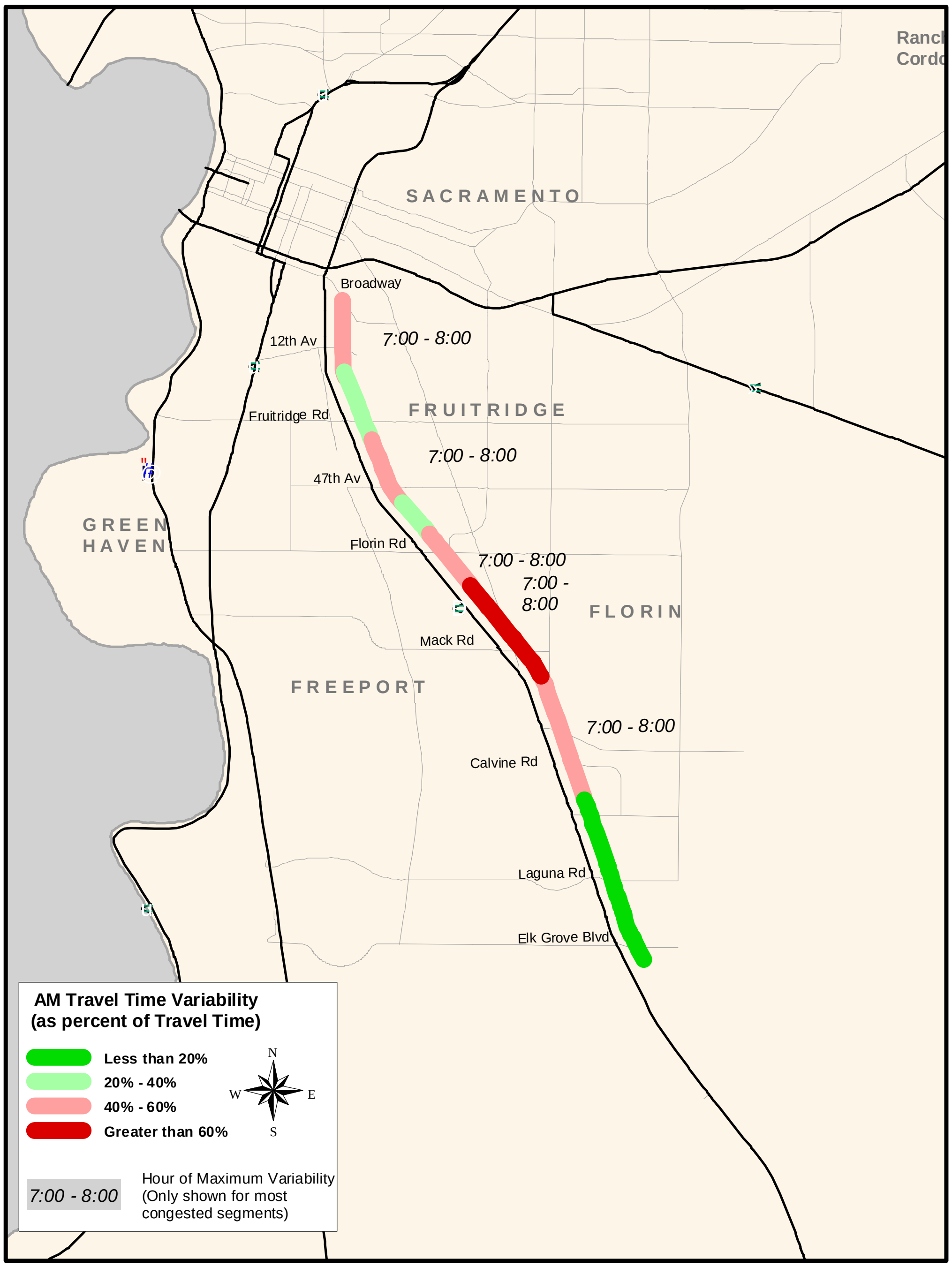
Dividing the standard deviation by the average time spent traveling produces the percent variability of a highway segment as follows:

$$\text{Travel Time Variability (Reliability)} = \frac{\text{Standard Deviation of Travel Time}}{\text{Average Travel Time}}$$

The reliability indicator uses the same loop detector data that is used to derive the mobility indicator. Data was collected from District 3 loop detectors from August 27 to December 24, 1999, providing 102 weekdays of data to use in this analysis.

Exhibit 2-7
Travel Time Reliability for the SR-99 Corridor by Time Period

Average AM Period Reliability



Average PM Period Reliability

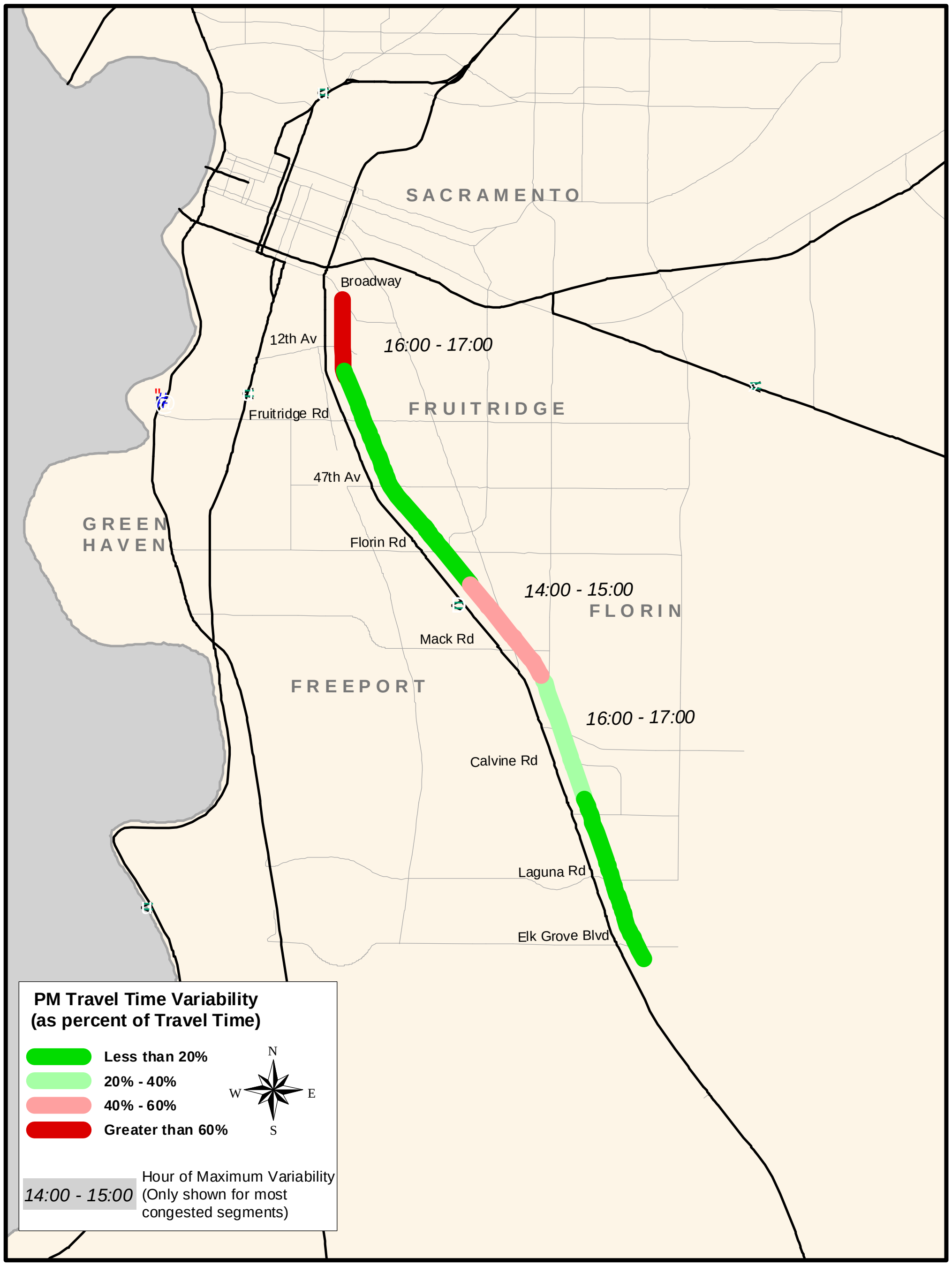


Exhibit 2-8
Segments on the SR-99 Northbound Corridor with Poor Reliability (60% or higher Variability)

AM Peak Period

Location Description	Facility/ # Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total AM Delay (hours)	Hour of Maximum Delay
Laguna Rd to Mack Rd	3	1.9	40.3	4155	1.75	2.83	1.07	335	7:00 - 8:00
Mack Rd to Florin Rd	3	1.8	28.2	3616	1.66	3.83	2.17	588	7:00 - 8:00
47th Ave to Fruitridge Rd	3	1.1	30.5	1381	1.02	2.16	1.15	119	7:00 - 8:00

PM Peak Period

Location Description	Facility/ # Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total PM Delay (hours)	Hour of Maximum Delay
Laguna Rd to Mack Rd	3	1.9	40.3	3229	1.75	2.83	1.07	376	14:00 - 15:00
Mack Rd to Florin Rd	3	1.8	28.2	1954	1.66	3.83	2.17	459	14:00 - 15:00
47th Ave to Fruitridge Rd	3	1.1	30.5	2202	1.02	2.16	1.15	274	16:00 - 17:00

Summary

Reliability is a relatively new indicator used to describe the traveler's experience. Therefore, the interpretation of the results is in the earliest stages of development. However, some generalizations about reliability can be made. Travel time variability below 20 percent can be considered to be normal. Variability exceeding 40 percent are consistent with congested periods. During the peak of the peak period, travel time reliability can improve (i.e., variability declines) as capacity has been reached and travel speeds remain consistently low. The highest variability tends to occur at the beginning or end of the peak period. As the peak period winds down, the number of vehicles on the roadway begins to decline, but stop-and-go traffic conditions remain until the number of vehicles is reduced so that free-flow conditions are reached. Therefore, a driver can experience relatively low delay and still experience high variability in travel time.

In the AM period, the worst reliability occurs near Calvine Avenue between 5:00 AM and 6:00 AM. In the PM period, most congestion along this northbound segment occurs between 47th Avenue and 12th Avenue in Sacramento.

Comparison with PSR

Since the reliability measure is new, it is not used in PSR reporting. Therefore, it is difficult to make a direct comparison to the results of this analysis to the results found in the PSR report.

3. DISTRICT 11 ANALYSIS

3.1 Corridor Description

The District 11 corridor analyzed is I-5 from downtown San Diego to Oceanside. This corridor covers nearly 39 miles and has loop detectors on both directions along the corridor, but these detectors do not cover the entire segment.

Northbound, the corridor has 31 miles of loop coverage from Hawthorne Street in San Diego to Cannon Road in Encinitas. In the southbound direction, over 36 miles are covered. These loops provide data from 7th Avenue in San Diego to Mission Avenue in Encinitas. The table listing each loop location by post mile is shown below in Exhibit 3-1 on the following page.

This I-5 segment has between 4 and 6 lanes and runs through a range of urban and suburban areas. From downtown San Diego to the I-8 interchange, the area can be described as distinctly urban. North of I-8 land uses alternate widely from suburban to rural. On and off-ramps distances vary widely from 1/2 mile to several miles between interchanges.

As with the other pilot study, the results section is organized in three parts:

- safety results
- mobility results
- reliability results.

The safety results are reported for the original, 13-mile segment covering both directions. The mobility and reliability results are reported for the northbound and southbound direction.

Note that safety results are based on 7-day (weekday and weekend) accident data, while mobility and reliability results are based on 5-day data (weekday only).

Exhibit 3-1
District 11 I-5 Loop Locations

PM	Location	Loop Detectors	
		Northbound	Southbound
15.9	7th Avenue		4
16.9	Hawthorne Street	4	
17.3	India Street	4	
17.4	Kettner Boulevard		4
18.2	Hancock Street		4
18.3	San Diego Avenue	4	
19.0	Old Town/Moore Street	4	4
20.8	Sea World Drive	4	4
22.3	Clairemont Drive	4	4
23.5	Balboa Avenue		4
23.9	Mission Bay Drive	4	4
26.8	Gilman Drive		4
28.0	Nobel Drive		4
28.5	La Jolla Villge Drive	4	4
33.0	Carmel Valley Road	4	4
34.2	Del Mar Heights Road		4
36.2	Via de la Valle		4
37.5	Lomas Santa Fe Drive	4	
38.6	Manchester Avenue	4	4
39.6	Birmingham Drive		4
40.5	Santa Fe Drive		4
41.4	Encinitas Boulevard		4
42.7	Leucadia Boulevard	4	4
44.1	La Costa Avenue	4	4
45.6	Poinsettia Lane	4	4
47.0	Palomar Airport Road	4	4
48.0	Cannon Road	4	4
49.3	Tamarack Avenue		4
50.1	Carlsbad Village		4
50.7	Las Flores Drive		4
51.5	Cassidy Street		4
52.3	Oceanside Boulevard		4
52.5	Mission Avenue		4

Source: District 11 Traffic Operations

3.2 Safety Results

The source for the safety results is the 1999 Route Segment Report (RSR). This data source is linked to Traffic Accident and Surveillance Analysis System (TASAS), which is based on California Highway Patrol accident reports. The 1999 Route Segment Report safety statistics contain total accidents for 1996, 1997 and 1998. The statistics shown therefore represent the average safety rates for the three-year period.

The segments from the RSR chosen as best corresponding to the corridor desired are shown below in Exhibit 3-2.

Exhibit 3-2
District 11 Pilot RSR Analysis Sample – Segment Descriptions

CO	RTE	SEG ID	PM	PM	FROM	TO	R/U	SEG LGTH	EXIST FAC
SD	005	00545P	R025.94	R028.42	JCT RTE 52	LA JOLLA VILLAGE DR	U	2.5	8F
SD	005	00547P	R028.42	R030.68	LA JOLLA VILLAGE DR	NORTH JCT RTE 805	U	2.3	8F
SD	005	00549P	R030.68	R032.90	NORTH JCT RTE 805	RTE 56 (CARMEL VALLEY RD)	U	2.2	8F
SD	005	00551P	R032.90	R036.26	RTE 56 (CARMEL VALL	VIA DE LA VALLE	U	3.4	9F
SD	005	00553P	R036.26	R038.67	VIA DE LA VALLE	0.1 MI NO OF MANCHESTER AV	U	2.4	8F
SD	005	00555P	R038.67	R041.50	0.1 MI N OF MANCHEST	ENCINITAS BLVD	U	2.8	8F

Source: 1999 Route Segment Report

For each segment, the RSR lists the segment length, the Annual Average Daily Traffic (AADT), the Traffic - Daily Vehicle Miles (T-DVM) traveled on that segment (i.e., also know as vehicle miles traveled), as well as the accident totals and accident rates as calculated by Caltrans. The accident rate calculation uses as its primary (but not only) factor, T-DVM for the facility and that segment. These are shown in Exhibit 3-3 below:

Exhibit 3-3
District 11 Pilot RSR Analysis Sample – Safety Data

CO	RTE	PM	PM	SEG LENGTH	AADT ('000s)	T-DVM ('000s)	ACCIDENT RATE
SD	005	R025.94	R028.42	2.5	372	24	0.37
SD	005	R028.42	R030.68	2.3	304	331	0.77
SD	005	R030.68	R032.90	2.2	508	605	0.89
SD	005	R032.90	R036.26	3.4	733	536	0.68
SD	005	R036.26	R038.67	2.4	496	228	0.43
SD	005	R038.67	R041.50	2.8	502	301	0.44

Source: 1999 Route Segment Report

Summary

By calculating the weighted average accident rate over the length of the corridor (weighted by VMT), one can calculate the overall accident rate for the entire corridor. The overall accident rate for the highway corridor for the D11 pilot is shown below in Exhibit 3-4.

The overall accident rate can be broken into auto and truck accident rates using a percentage basis as shown. In addition, fatality accident rates and injury accident rates can be computed in a similar way. Note that two thirds of all accidents do not involve any fatalities or injuries. This is consistent with the D3 pilot study.

Exhibit 3-4
District 11 I-5 Pilot - Highway Safety Results

Overall accident rate:	0.603 accident per million VMT
Auto accident rate	0.599 accident per million VMT
Truck accident rate:	0.004 accident per million VMT
Fatality accident rate:	0.002 accident per million VMT
Injury accident rate:	0.190 accident per million VMT

Source: 1999 Route Segment Report, Booz·Allen analysis

All accident rates are expressed in total million VMT, not auto VMT or truck VMT. The total includes both truck and auto types.

Comparison with PSR

An effort was made to compare the results of this safety analysis to safety numbers presented in the January 2000 Project Study Report (PSR) for the same corridor[2].

The comparison was difficult because the PSR referenced Table B in TASAS for the July 1996 to June 1999 totals. The Booz Allen analysis relied on the 1996-1998 average rates so there is a six-month lag on either side of the data set. The other challenge was that the PSR addressed *fatalities* per VMT whereas the Booz Allen team analyzed *fatality accidents* per VMT. Nevertheless, the numbers found for the Del Mar Heights Road to Encinitas Boulevard were comparable (i.e., 0.002 versus 0.0013 for the PSR). Also, the PSR listed total accidents (965 for the three year period on the segment), not any overall accident rate.

2 *Caltrans District 11, Project Study Report (Project Development Report), On Interstate 5 Between Del Mar Heights Road in the City of San Diego and Vandegrift Boulevard in the City of Oceanside, January 2000*

Rail Safety

The project team also contacted the Public Utilities Commission to report on inter-regional rail safety statistics. The PUC reported that during 1998, seven (7) accidents took place along the pilot study corridor. Details are shown in Exhibit 3-5 below.

Exhibit 3-5
Rail Safety Statistics for D11 Pilot

Railroads	Accidents	Categories	Fatalities	Injuries
Amtrak	5	Grade Crossings (3); Trespassers (2)	3	1
Freight Railroads	2	Operations/ Mechanical	2	0
Total	7		5	1

Source: Public Utilities Commission, Los Angeles Office

It is possible to calculate passenger and freight rail safety rate information, but for California as a whole. This is feasible because usage statistics are available at the State level. The PUC does not maintain train-mile information at a sub-state level.

3.3 Mobility Results

Highway mobility results were developed by using loop detector data provided by District 11. Mobility is defined as the average point-to-point travel times resulting in travel delay. Delay is the additional travel time spent traveling due to less than optimal circumstances[3]. The highway mobility manual guidelines developed for this phase of the performance measures project were used to derive the mobility results for this pilot study.

In total, 87 weekdays (between August 3 and November 30, 1999) of data were collected from the loops on I-5. The loop detector data provide the following information:

- loop location (e.g., i.d. number, route number, direction, postmile)
- date
- time

3 *Note that the performance measure initiative definition of delay differs from the Caltrans Highway Congestion Monitoring (HICOMP) report methodology. The HICOMP report outlines all delay corresponding to speeds less than 35 miles per hour. The delay captured in this report is any delay due to travel at less than the posted speed limit. For more information on the mobility indicator, please consult the Transportation System Performance Measures, Compendium of Phase II Results, June 30, 1999.*

- speed
- traffic volume
- number of lanes at that location
- number of loops reporting data (not all lanes are equipped with working loop detectors).

Delay along a segment is calculated by subtracting free-flow travel time from the actual average travel time. The free-flow travel time is determined by the posted speed (i.e., Free-Flow Travel Time = Distance ÷ Posted Speed). Actual average travel time is determined by the actual speed of travel over the same distance.

To arrive at delay for any given time period (e.g., AM or hourly), the travel time for each segment of the highway is calculated for each day for that time period. The average travel time across the segment is the summation of all the travel times for all the days per time period divided by the total number of days for which there is data as illustrated in the following formula:

$$\text{Average Travel Time} = \left(\frac{\sum \text{Travel Times Across the Segment}}{\text{Total Number of Days of Data}}\right)$$

The loop detector was first scrutinized for reasonableness. "Invalid" loop detector data were information that represented:

- very little data reported (i.e., only one or two days of data)
- consistently very high speeds (i.e., in excess of 80 mph)
- consistently very high volumes (i.e., more than 2,800 vehicles per hour per lane).

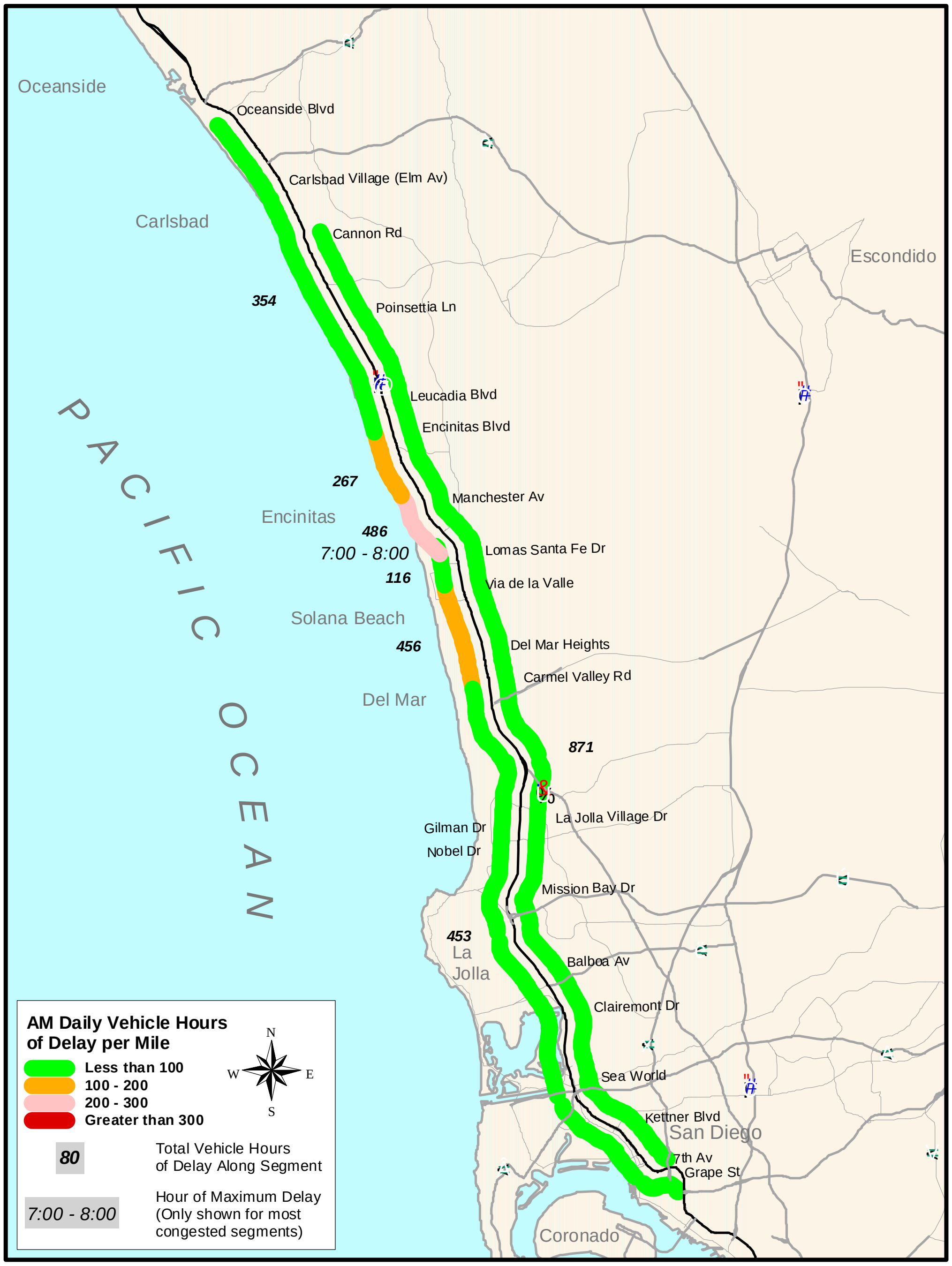
The AM period selected represents the time from 5:30 AM to 10:00 AM. The PM period represents the time from 1:30 PM to 8:00 PM.

Exhibit 3-6 shows the results of the delay analysis along the corridor for the AM and PM periods. Exhibit 3-7 presents the same data in tabular form.

Again, when comparing the tabular and graphical data, note that each total delay figure represents a *grouping* of segments experiencing similar levels of delay. The total delay shown represents the summation of the delay experienced on each individual segment.

Exhibit 3-6
Average Daily Vehicle-Hours of Delay for the I-5 Corridor by Time Period

Average AM Period Daily Delay



Average PM Period Daily Delay

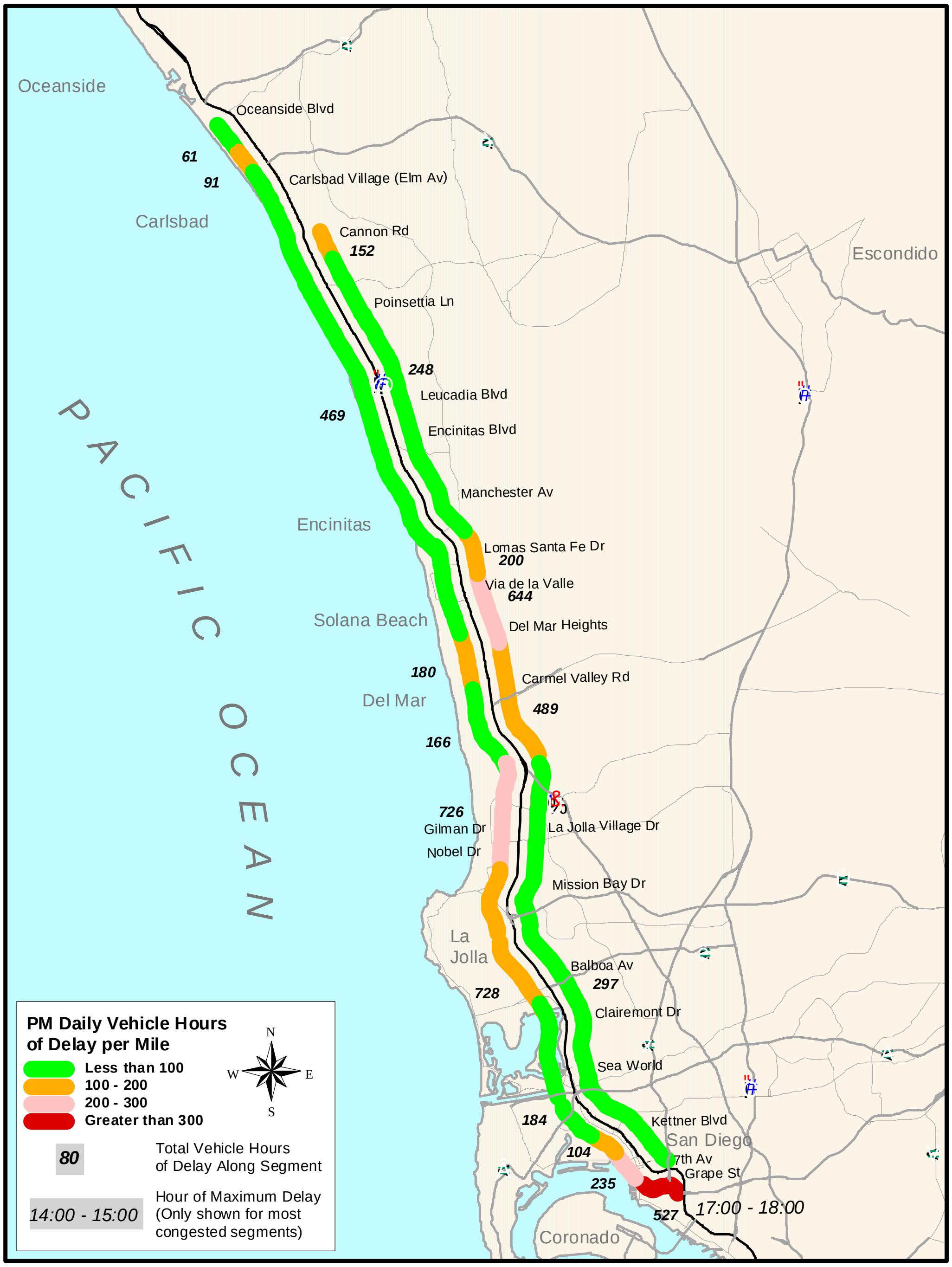


Exhibit 3-7
Segments Showing Highest Average Daily Vehicle Hours of Delay for the I-5 Corridor

AM Commute Period
Southbound

Location Description	Facility/# Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total AM Delay (hours)	Hour of Maximum Delay
Encinitas Blvd to Manachester Ave	4	1.9	52.9	8874	1.75	2.155	0.40	267	7:00 - 8:00
Manachester Ave to Lomas Santa Fe Dr	4	2.2	48.6	9475	2.03	2.716	0.69	487	7:00 - 8:00
Via de la Valle to Carmel Valley Rd	4	3.2	48.9	6252	2.95	3.926	0.97	456	8:00 - 9:00

PM Commute Period
Northbound

Location Description	Facility/# Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total PM Delay (hours)	Hour of Maximum Delay
Carmel Valley Rd to Via de la Valle	4	2.5	49.0	7889	2.31	3.061	0.75	644	17:00 - 18:00

Southbound

Location Description	Facility/# Lanes	Segment Length (miles)	Average Speed	Est Avg Hourly Volumes	Free Flow Travel Time (minutes)	Average Travel Time (minutes)	Delay per Veh (minutes)	Total PM Delay (hours)	Hour of Maximum Delay
Carmel Valley Rd to Nobel Dr	4	3.2	52.9	9919	2.95	3.629	0.68	726	17:00 - 18:00
Kettner Blvd to 7th Ave	5	1.15	44.6	4468	1.06	1.547	0.49	235	17:00 - 18:00
7th Ave and Grape St	5	1.3	44.6	8863	1.20	1.749	0.55	527	17:00 - 18:00

Summary

The above analysis reveals that the portion of I-5 from San Diego to Oceanside is severely congested along most of the corridor during both AM and PM peak periods. The most congestion occurs between Carmel Valley Road and Leucadia Boulevard.

Most delay in the AM period is concentrated over three segments between Carmel Valley Road and Encinitas Boulevard Southbound. These segments combined, account for over 50 percent (1,210 vehicle-hours) of all AM delay along the corridor occurring along this 13-mile stretch of freeway. The peak hour for delay is 7:00 to 8:00 AM or 8:00 to 9:00 AM for these segments. The highest concentration of delay occurs between Manchester Avenue and Lomas Santa Fe Drive with 487 hours of vehicle delay.

The PM period delay is considerably higher than the AM delay along the corridor at 5,501 average daily vehicle-hours of delay. Several segments contribute significant congestion during the PM period, although just under one-third of this congestion occurs along a 12-mile stretch in the southbound direction. In the northbound direction, nearly one-quarter of all delay occurs in the area south of Carmel Valley Road to Lomas Santa Fe Road. The peak hour for congestion along this I-5 corridor is 17:00 to 18:00.

Comparison with PSR

This analysis was compared to the most recent Project Study Report developed by Caltrans. The analysis presented in this memo corresponds closely to the results of the PSR. In the "Need and Purpose" section of the PSR, the highest levels of average daily traffic was reported in the Del Mar Heights Road area, with the worst Levels of Service (LOS) also occurring in that area for both the AM and PM peaks. This analysis shows that the highest levels of delay occur around the Carmel Valley Road / Del Mar Heights Road areas in both the AM and PM peak. It also reveals that high levels of delay occur in Encinitas between Birmingham Road and Leucadia Road during the AM commute period . The PSR indicates significant levels of traffic congestion around Encinitas Road, between the two roads.

3.4 Reliability Results

Reliability is defined as day-to-day variability in travel time between the expected travel time and the actual travel time. Reliability can be calculated by using statistical tools. The standard deviation is one tool to estimate how much the travel time on any given day will "deviate" from the average travel time. It provides the probable range of time that a motorist will arrive within his or her scheduled time.

$$\text{Standard Deviation of Travel Time} = \sqrt{\frac{\sum(\text{Travel Time on Day } n \text{ - Average Travel Time})^2}{\text{Number of Days - 1}}}$$

Dividing the standard deviation by the average time spent traveling produces the percent variability of a highway segment as follows:

$$\text{Travel Time Variability (Reliability)} = \frac{\text{Standard Deviation of Travel Time}}{\text{Average Travel Time}}$$

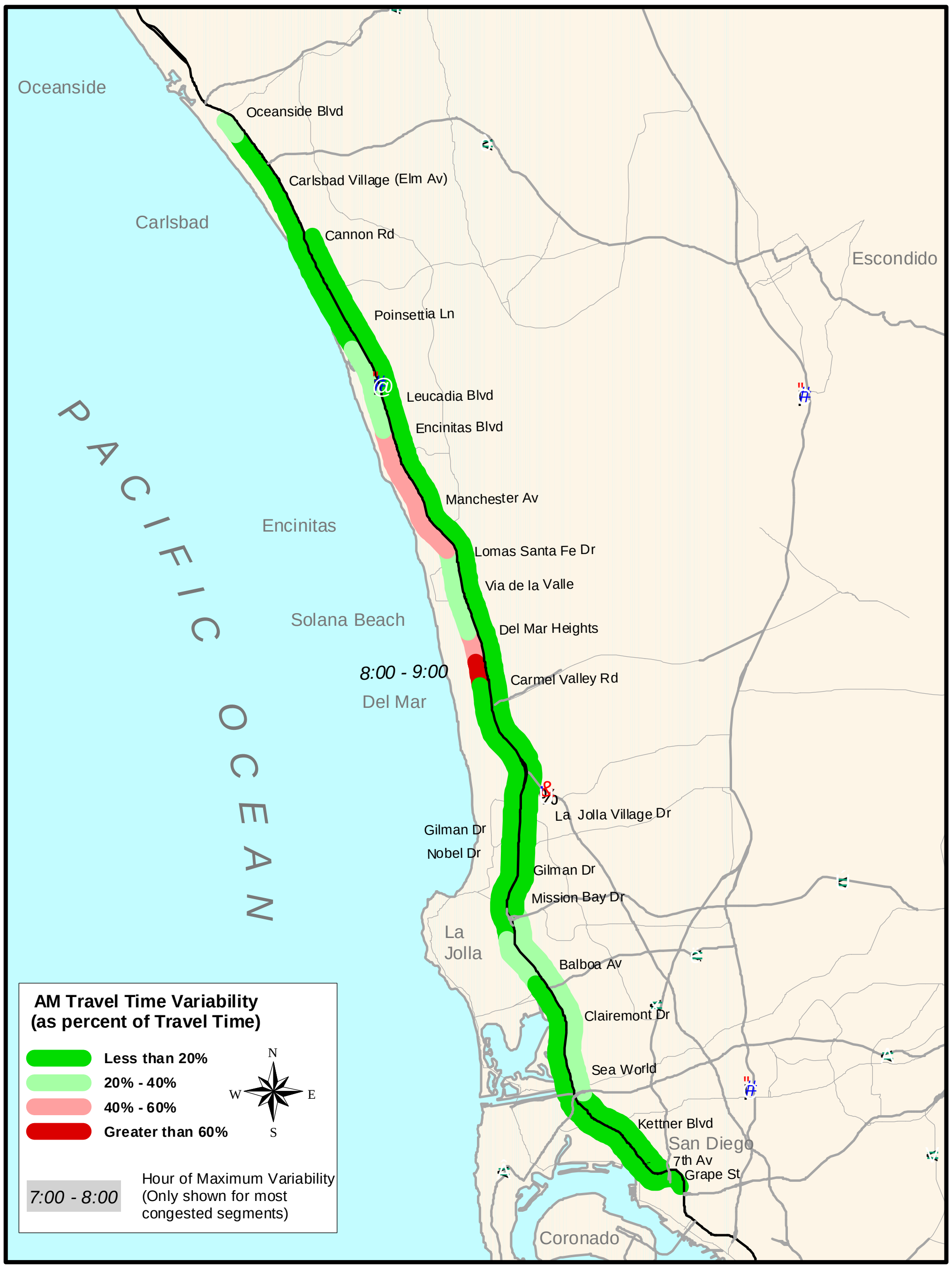
The reliability indicator uses the same loop detector data that is used to derive the mobility indicator. Data was collected from District 11 loop detectors from August 3 to

November 30, 1999, providing a total of 87 weekdays of data to use in this analysis for the I-5 segment in San Diego County.

The results of the reliability analysis between Carmel Valley Road in Del Mar and Birmingham Road in Encinitas are shown below in Exhibit 3-8 and Exhibit 3-9.

Exhibit 3-8
Travel Time Reliability for the I-5 Corridor by Time Period

Average AM Period Reliability



Average PM Period Reliability

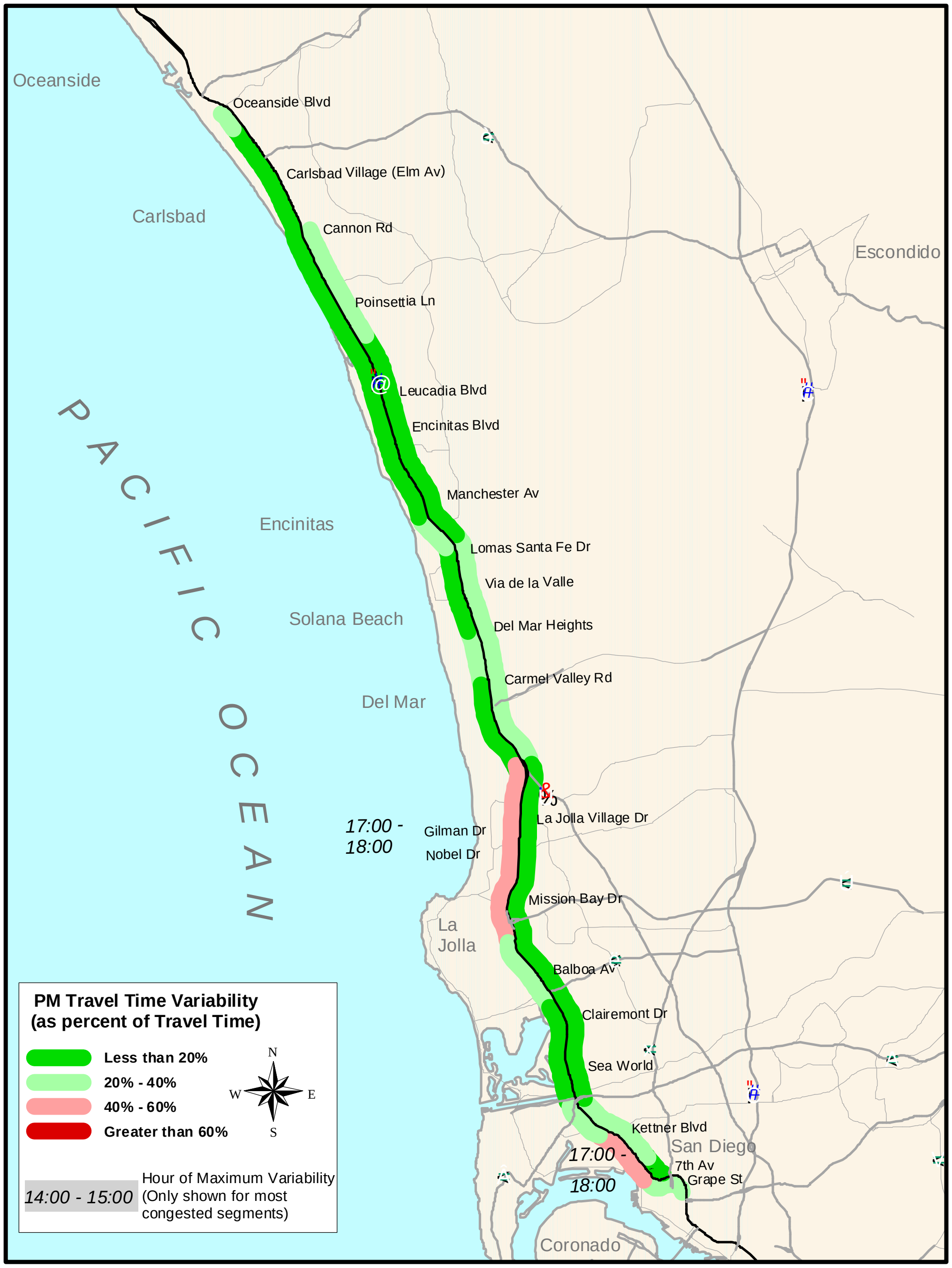


Exhibit 3-9
Segments on the I-5 Corridor with Poor Reliability (60% or higher Variability)

AM Peak Period

Route	Direction	Location Description	From PostMile (Est.)	To PostMile (Est.)	Hour of Worst Reliability (Maximum Variability)
5	N	Hawthorne St to Wash/San Diego Ave	16.4	18.7	8:00 - 9:00
5	S	Near Mission Bay/Grand	23.7	25.4	5:00 - 6:00
5	S	Near Del Mar Heights Rd	33.5	35.2	9:00 - 10:00
5	S	Near Manchester Av	37.9	39.1	9:00 - 10:00
5	S	Santa Fe Dr to Encinitas Blvd	40.1	42.0	8:00 - 9:00
5	S	Near Mission Ave	52.4	53.0	8:00 - 9:00

PM Peak Period

Route	Direction	Location Description	From PostMile (Est.)	To PostMile (Est.)	Hour of Worst Reliability (Maximum Variability)
5	N	Near India St	17.1	17.8	17:00 - 18:00
5	N	Near Carmel Valley Rd	30.7	34.6	13:00 - 14:00
5	S	Kettner Blvd to Old Town Ave	16.7	19.9	16:00 - 17:00
5	S	Balboa Ave to Mission Bay/Grand	22.9	25.4	14:00 - 15:00
5	S	Nobel Dr to La Jolla Village Rd	27.4	30.6	17:00 - 18:00
5	S	Near Del Mar Heights Rd	33.5	35.2	14:00 - 15:00
5	S	Lomas Santa Fe Dr to Encinitas Blvd	36.7	42.0	13:00 - 14:00
5	S	Near Mission Ave	52.4	53.0	16:00 - 17:00

Summary

Reliability is a relatively new indicator used to describe the traveler's experience. Therefore, the interpretation of the results is in the earliest stages of development. However, some generalizations about reliability can be made. Travel time variability below 20 percent can be considered to be normal. Variability exceeding 40 percent are consistent with congested periods, while variability exceeding 60 percent can be considered to be poor. During the peak of the peak period, travel time reliability can improve (i.e., variability declines) as capacity has been reached and travel speeds remain consistently low. The highest variability tends to occur on the shoulders of the peak. As the peak period winds down, the number of vehicles on the roadway begins to decline, but stop-and-go traffic conditions remain until the number of vehicles is reduced so that free-flow conditions are reached. Therefore, a driver can experience relatively low delay and still experience high travel time variability.

All segments listed in Exhibit 3-9 show over 60 percent travel time variability. The worst reliability is shown to occur at Del Mar Heights Road during the AM commute period in both the north and southbound directions. In the southbound direction, the rest of the segment from Birmingham Drive also exhibits high levels of variability, which tends to occur on the shoulder of the peak period (i.e., 9:00 AM to 10:00 AM).

It is important to note that the northbound direction shows very high reliability during both the AM and PM commute periods. This may indicate that travelers heading northbound along I-5 may not experience the same level of dissatisfaction with their trips as someone traveling southbound. Delay is higher in the northbound PM direction than in the southbound AM or PM direction, but the lower variability in travel time may not make the commute seem worse to the individual traveler.

Comparison with PSR

Since the reliability measure is new, it is not used in PSR reporting. Therefore, it is difficult to make a direct comparison to the results of this analysis to the results found in the PSR report.